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FUEL COOLANT THERMAL INTERACTION PROJECT

UC 79P

Massachusetts Institute of Technology
Departments of Nuclear and Mechanical Engineering

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DISCLAIMER

Reports and Papers Published under MIT Fuel-Coolant Interaction Project

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Progress Reports (Available from National Technical Information Service, U.S. Department of Commerce, Springfield, Va. 22151)

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Mujid S. Kazimi, "Theoretical Studies on Some Aspects of Molten Fuel-Coolant Thermal Interaction," 31-109-38-2831-1TR, MITNE-155, May 1973.

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Trond A. Bjornard, "An Experimental Investigation of Acoustic Cavitation as a Fragmentation Mechanism of Molten Tin Droplets in Water," 31-109-38-2831-3TR, MITNE-163, May 1974.

Glen Bjorkquist, "An Experimental Investigation of the Fragmentation of Molten Metals in Water," 31-109-38-2831-4TR, June 1975.

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William F. Lenz, Jr. "Mixing Requirements for the Limiting Fuel-Coolant Interactions in Liquid Metal Fast Breeder Reactors," COO-2781-8TR, November 1976

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Introduction

The objective of the continued work on this project at M.I.T. is to experimentally and analytically study the dominant mechanisms in fuel coolant thermal interactions which could lead to vapor explosions. Our exploration of mechanisms is focused in three areas:

I) Mechanisms responsible for fragmentation in molten metal droplet experiments (here we will include assessment of the validity of the proposed Spontaneous Nucleation Mechanism),

II) Thermal Stress Initiated Fracture as a fragmentation mechanism (this mechanism is not considered responsible for the fragmentation of molten metal drops - see Knapp's work),

III) Possible mechanisms of energy dissipation due to heat transfer during the HCDA expansion.

Work is being performed simultaneously in these areas and will be briefly described below.

I. Mechanisms Responsible for Fragmentation in Molten Metal Droplet Experiments (Michael Corradini)

There has been a large amount of experimental data accumulated for the tin-water system of simulant materials. The effects of research groups in England (Culham Laboratory and CEGB) and in the U.S. (MIT and UCLA) have succeeded in identifying a number of dependent variables which affect the degree of interaction (extent of fragmentation, peak pressure generation) in the tin-water system: initial fuel temperature, initial coolant temperature, size of the mass of tin, shape of the mass, and effects of external triggers on interaction.

It has been the intent during this period of work to organize the data of the tin-water system in a systematic fashion so that the effects of these variables become apparent and can be analyzed. The analysis will center around a review of the spontaneous nucleation theory and an attempt to apply its principles to the tin-water data. This approach has never been done before and it seems that it would be useful as a check of the theory.

II. Thermal Stress Initiated Fracture
(W.F. Lenz)

The work in this area has been submitted in a topical report COO-2781-8TR, "Mixing Requirements for the Limiting Fuel-Coolant Interactions in Liquid Metal Fast Breeder Reactors." The major thrust of this report is to:

(i) establish a conservative upper bound on the mixing requirements for a fuel coolant interaction in a TOP (mixing time constant and final fuel particle size) that would give a slug impact energy greater than design for the FRTR or the CRBR,

(ii) compare this conservative upper bound to the mechanistic failure rates in both reactor systems to determine the realistic mixing time requirements,

(iii) compare the margin of safety in both designs for the TOP accident.

The results indicate that the realistic mixing requirements for the fuel coolant interaction are at least an order of magnitude into the safe region for an FCI compared to worst conditions. This approach is useful because a conservative upper bound has been established to compare future mechanistic designs with to obtain a feel for the inherent safety margin.

III. Possible Mechanisms of Heat Transfer to Cold Walls and Fluid in Reactor Vessel

(Michael Corradini)

The overall accident sequence of the transient overpower without scram has been modeled by computer codes (e.g., SAS). Additionally scaled experiments have been done to model the pressure behavior and dynamic loading of the reactor during the accident. One specific set of experiments by the Stanford Research Institute simulates the expansion of a two phase mixture caused by a FCI in the core after the accident has occurred. During such experiments a large amount of heat transfer to the liquid water slug (simulating sodium) was noted reducing the work output of the scaled experiments considerably. This suggested that the abiabatic condition used in the computer model may be inherently conservative.

A topical report COO-2781-9TR is being issued which looks at this subject in an initial analysis. The results indicate:

(i) The amount of heat transfer is large (∿90%) in comparison to the work output in the scaled tests

(ii) A simple heat transfer model based on the heat transfer mechanism of area enhancement due to Taylor instabilities was developed. In comparison to the experimental results reasonably good agreement is obtained.

(iii) The model and experimental results both indicate that the proportion of heat transferred energy to available work output in the SRI scaled tests remains constant (90% to 10%) with a change in scale. This suggests that the inherent heat transfer mechanism is not diminished with a change in scale, thus suggesting a large inherent safety margin.